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(54) **TOUCH PANEL AND METHOD OF FORMING THE SAME**

9,030,289 B2 * 5/2015 Lai G06F 3/045
338/47

(Continued)

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FOREIGN PATENT DOCUMENTS

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CN 1510768 A 7/2004
TW 201117071 5/2011

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(Continued)

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OTHER PUBLICATIONS

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G01L 1/16 (2006.01)

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(52) **U.S. Cl.**

CPC **G06F 3/0414** (2013.01); **G01L 1/16** (2013.01); **H01L 41/1132** (2013.01)

(58) **Field of Classification Search**

CPC G06F 3/0414; H01L 41/1132; G01L 1/16

USPC 345/173; 178/18.01–20.04

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

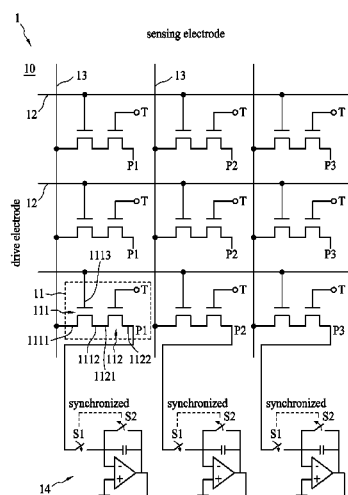
4,429,413 A * 1/1984 Edwards A61B 5/1172
257/E27.006

4,644,100 A 2/1987 Brenner et al.

(57) **ABSTRACT**

A touch panel comprises a plurality of basic sensing-units arranged in a matrix. The basic sensing-unit comprises a pressure-sensing transistor and a selection transistor. The pressure-sensing transistor comprises a first terminal, a second terminal, a gate electrode, a mask layer, a channel connecting the first and second terminals, a dielectric layer formed on the channel, and a piezoelectric material deposited on the dielectric layer. The piezoelectric material may comprise PVDF, lead zirconate titanate, ZnO, BaTiO₃, LiNbO₃, or PbTiO₃. The selection transistor comprises a first terminal, a second terminal, and a third terminal. The first terminal of the selection transistor connects to a sensing electrode of the touch panel, the second terminal of the selection transistor connects to the first terminal of the pressure sensing transistor, and the third terminal of the selection transistor is a transistor gate and connects to a drive electrode of the touch panel.

11 Claims, 7 Drawing Sheets



(56)

References Cited

U.S. PATENT DOCUMENTS

9,046,974 B2 * 6/2015 Cok G06F 3/044
 9,141,224 B1 * 9/2015 Rowe G06F 3/0414
 9,184,502 B2 * 11/2015 Yang H01Q 1/2266
 2004/0119903 A1 * 6/2004 Chang G02F 1/133516
 349/43
 2004/0120183 A1 6/2004 Appenzeller et al.
 2005/0065280 A1 3/2005 Subramaniam et al.
 2009/0326337 A1 * 12/2009 Solin G01N 15/1031
 600/300
 2010/0123671 A1 * 5/2010 Lee G01L 1/16
 345/173
 2010/0141599 A1 * 6/2010 Wang G06F 3/044
 345/173
 2010/0201651 A1 * 8/2010 Baucom G09F 9/372
 345/174
 2010/0265187 A1 * 10/2010 Chang G06F 3/044
 345/173
 2010/0288048 A1 * 11/2010 Harris G01L 9/0098
 73/584
 2011/0000060 A1 * 1/2011 Lee H01L 27/20
 29/25.35
 2011/0049579 A1 * 3/2011 Dumitru B82Y 10/00
 257/254
 2011/0108936 A1 * 5/2011 Meng G01L 1/005
 257/419
 2011/0227836 A1 * 9/2011 Li G06F 3/0414
 345/173
 2011/0239790 A1 * 10/2011 Kuczynski G01L 1/16
 73/862.624
 2011/0273651 A1 * 11/2011 Kim H01L 27/12
 349/110

2012/0256838 A1 * 10/2012 Lee H03K 17/9643
 345/168
 2013/0027326 A1 * 1/2013 Kim G06F 3/042
 345/173
 2013/0155017 A1 * 6/2013 Rehn G06F 3/0414
 345/174
 2013/0162570 A1 * 6/2013 Shin G06F 3/041
 345/173
 2014/0217853 A1 * 8/2014 Mankowski H02N 2/18
 310/319
 2014/0218334 A1 * 8/2014 Shibata G06F 3/044
 345/174
 2015/0138276 A1 * 5/2015 Abbott, Jr. B41J 2/1618
 347/40

FOREIGN PATENT DOCUMENTS

TW 201142683 12/2011
 TW 201209667 3/2012

OTHER PUBLICATIONS

English translation of Office Action and Search Report dated Mar. 18, 2015 from the Taiwan counterpart application 102107187, TW201117071, TW201142683 and TW201209667.
 Office Action dated Jul. 14, 2016 from the China counterpart application 201310142891.X.
 Search report dated Jul. 14, 2016 from the China counterpart application 201310142891.X.
 English abstract translation of the Office Action dated Jul. 14, 2016 from the China counterpart application 201310142891.X.
 US20040120183 corresponds to CN1510768A.

* cited by examiner

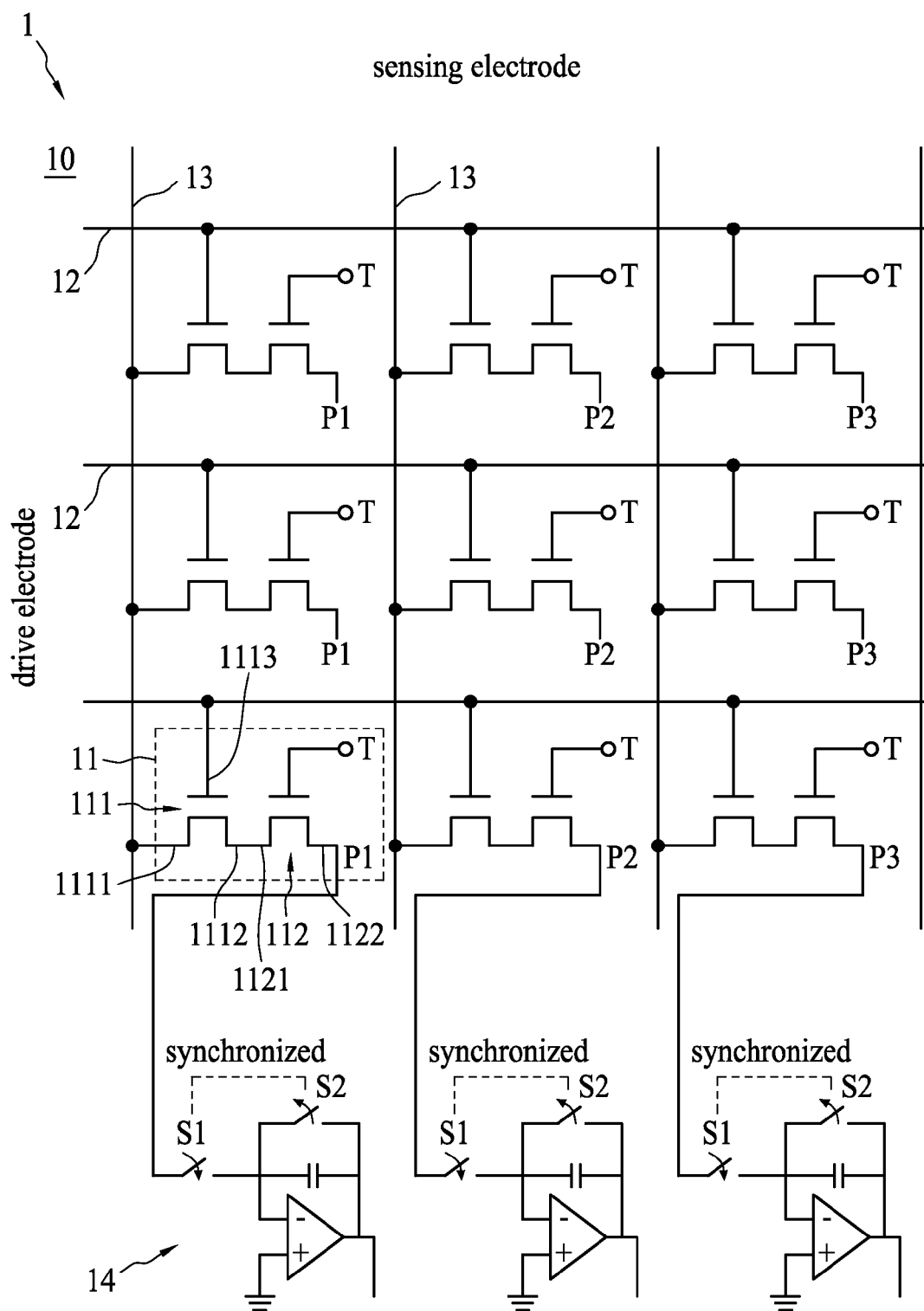


FIG. 1

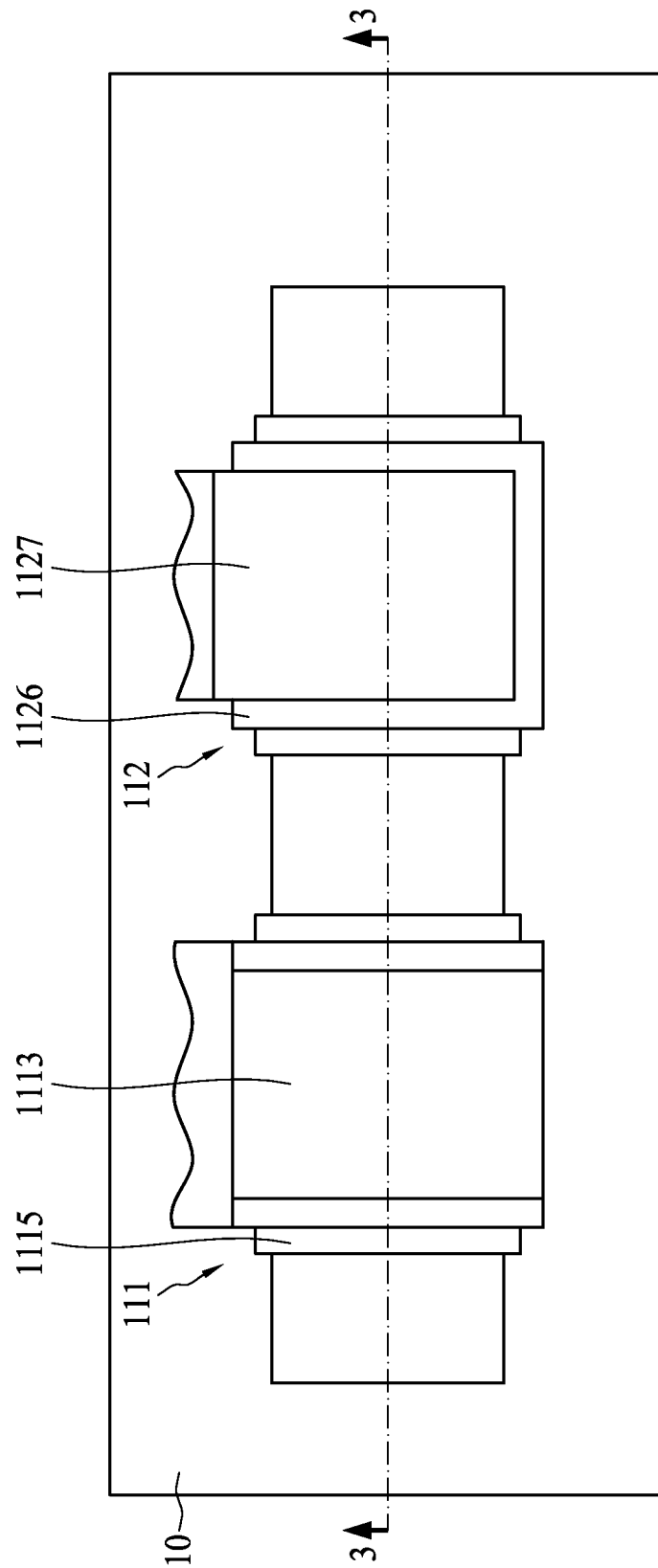


FIG. 2

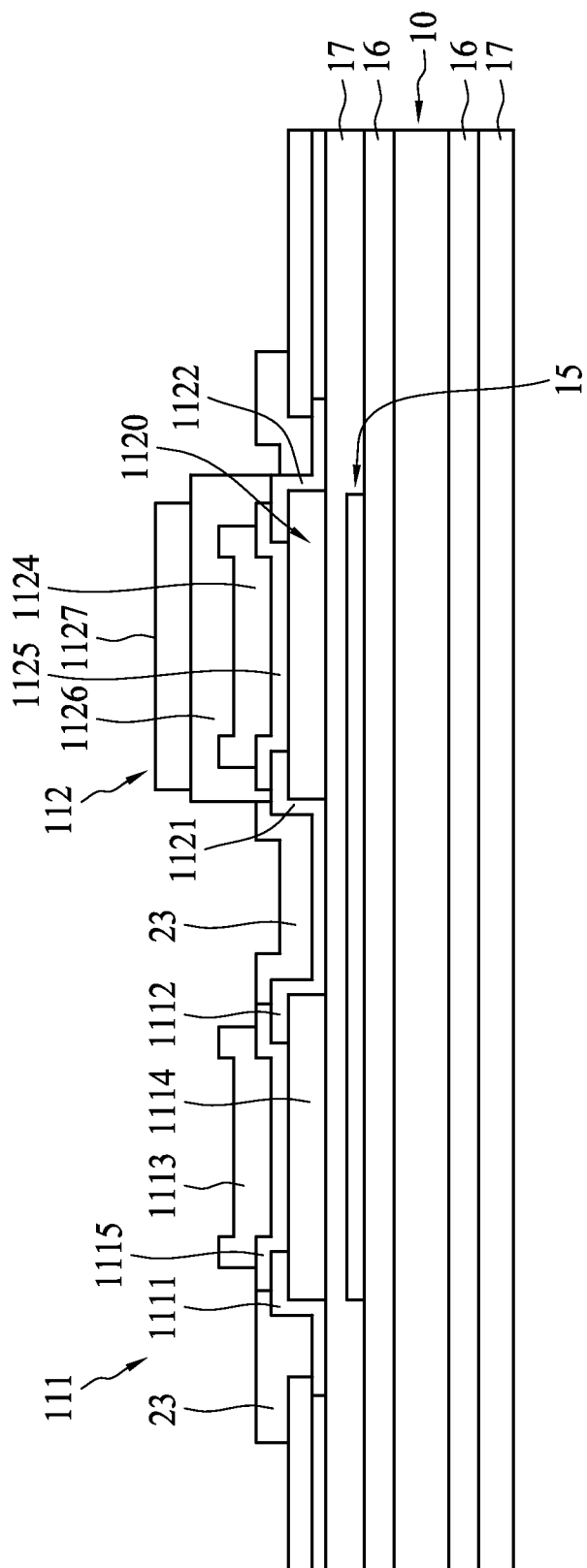


FIG. 3

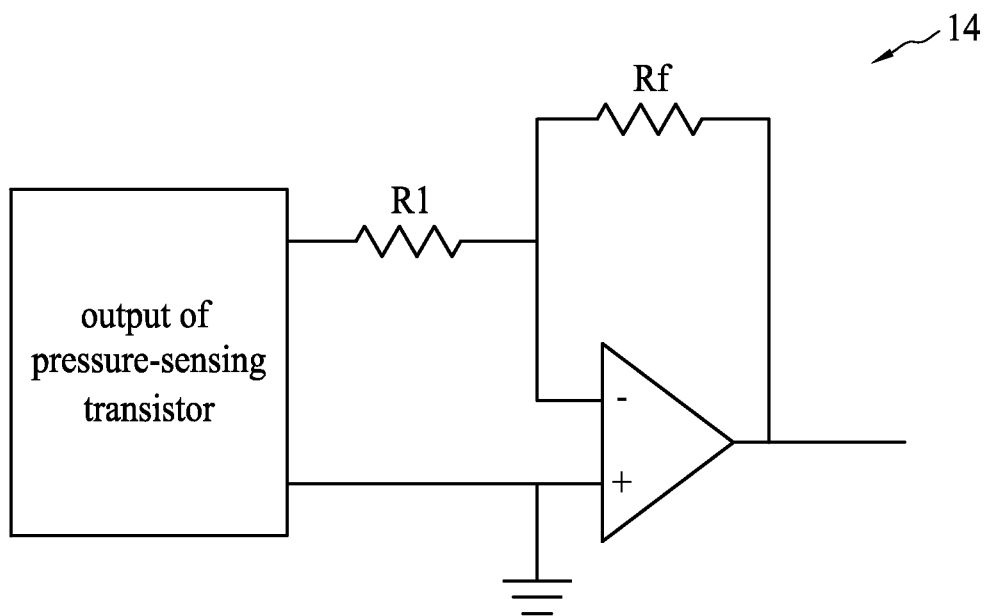


FIG. 4

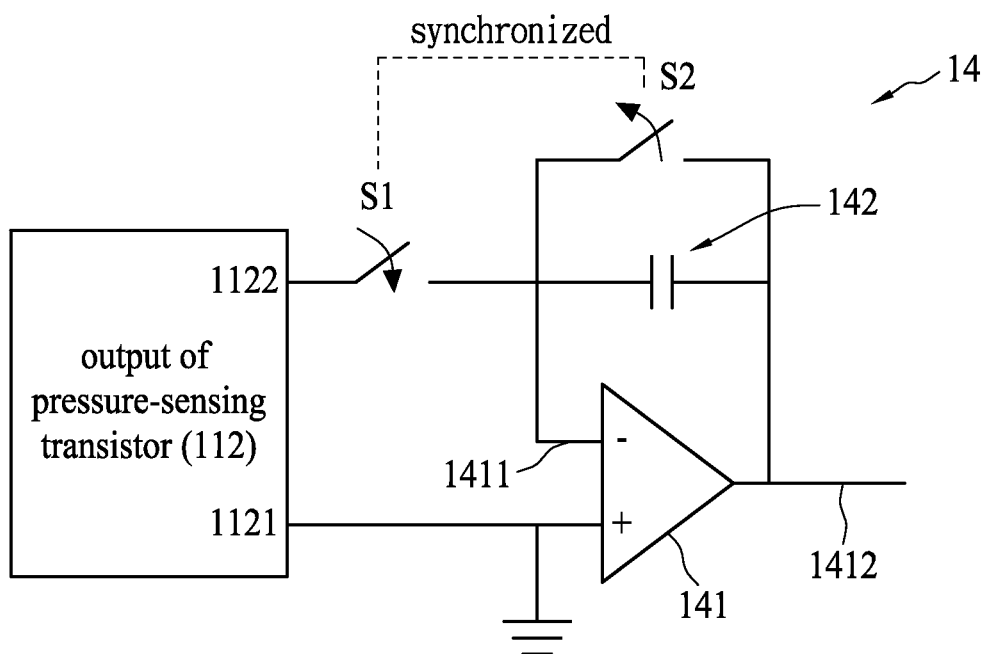


FIG. 5

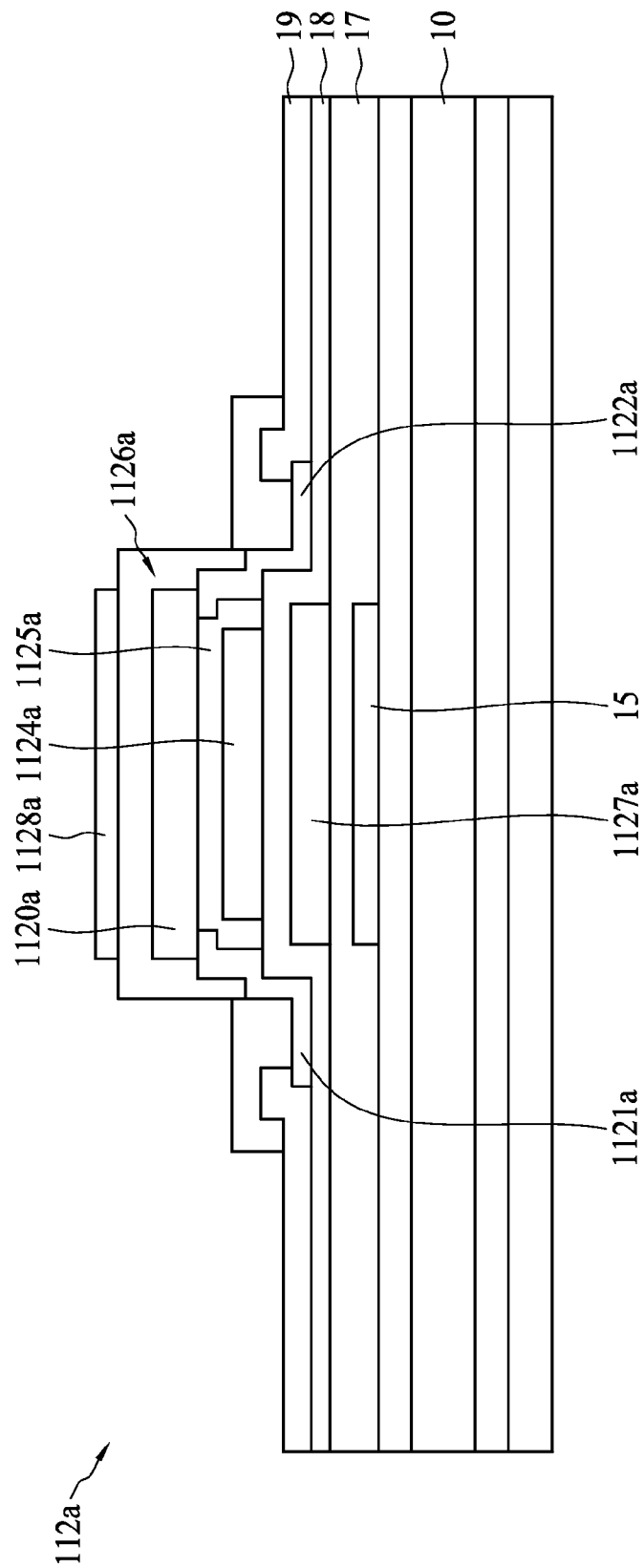


FIG. 6

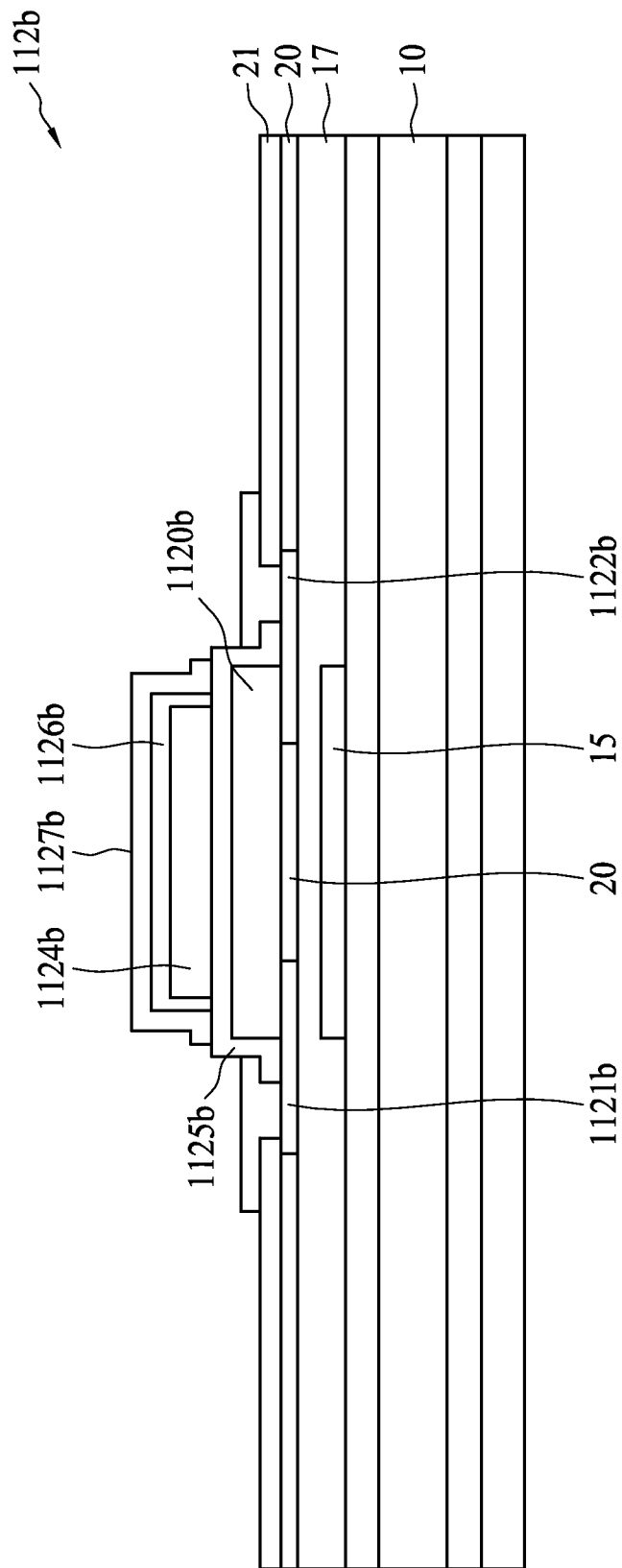


FIG. 7

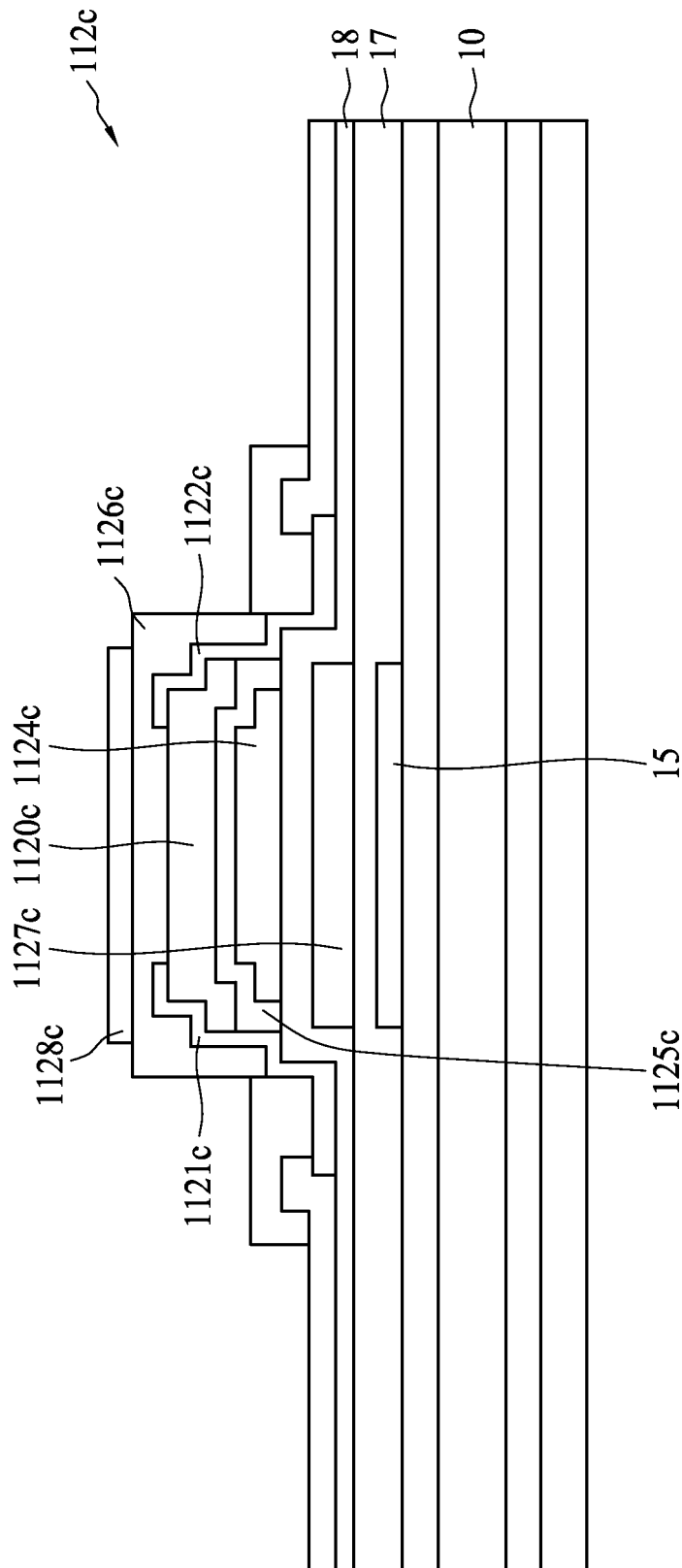


FIG. 8

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TOUCH PANEL AND METHOD OF FORMING THE SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a touch panel and a method of forming the same.

2. Description of the Related Art

Due to the popularity of computers, keyboards and optical mice, such devices have become some of the most commonly used data input apparatuses. However, because they are bulky and inconvenient to carry, a touch input device that can be combined with a screen is additionally being developed.

A touch panel can be operated either directly by a finger or by a stylus. A touch panel is a humanized input device that allows contact on a specific area on a panel to input a command. The trend of developing light, thin, short and small electronic products with complex functions has resulted in such electronic products having reduced space for housing additional parts; therefore, having a touch panel that occupies less space is suitable. In addition to simultaneously providing the functions of a keyboard and an optical mouse, a touch panel allows handwriting. Therefore, the touch panel is a best choice as a human-machine interface.

According to their operating principles, touch panels can be categorized into resistive, capacitive, optical, and surface acoustic wave types. A resistive type panel has a disadvantage of having low light transmittance; therefore, its brightness and contrast are low. A capacitive panel is easily affected by panel temperature and humidity, and its detection result varies with the ground voltage level; therefore, the capacitive panel has poorer stability. In addition, a capacitive panel cannot have a detection result if a nonconductor is used to operate. The resolution of an optical touch panel is determined by the number of infrared emitters and corresponding receivers applied on the optical touch panel; therefore, the resolution of an optical touch panel is restricted. A surface acoustic wave panel uses a transmit transducer to emit a surface wave and a receive transducer to receive the surface wave, and the surface acoustic wave panel determines a touch location according to the relationship between signal strength and time. U.S. Pat. No. 4,644, 100 discloses a surface acoustic wave touch device employing a single transmitting transducer and a single receiving transducer. Since sound waves are quite fast, a high speed signal processor and high performance analog/digital converter is required and results in high cost. However, lowering the cost will compromise the resolution.

The present touch panels still have several disadvantages and require further improvements.

SUMMARY OF THE INVENTION

In one embodiment of the present invention, a touch panel comprises a substrate, a plurality of transparent drive electrodes arranged in a matrix and formed on the substrate, a plurality of transparent sensing electrodes arranged in a matrix and formed on the substrate, and a plurality of basic sensing-units arranged in a matrix and formed on the substrate. Each sensing-unit comprises a pressure-sensing transistor and a selection transistor. The pressure-sensing transistor comprises a first terminal, a second terminal, a channel connecting the first and second terminals, a dielectric layer formed on the channel, and a piezoelectric material formed on the dielectric layer. The piezoelectric material comprises

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PVDF (polyvinylidene fluoride or polyvinylidene difluoride), or a mixture of PVDF and any one of lead zirconate titanate, zinc oxide, barium titanate, lithium niobate, or lead titanate. The selection transistor is formed on the substrate.

The selection transistor comprises a first terminal, a second terminal, and a third terminal. The first terminal of the selection transistor connects to a corresponding one of the sensing electrodes, the second terminal of the selection transistor connects to the first terminal of the pressure-sensing transistor, and the third terminal of the selection transistor is a transistor gate and connects to a corresponding one of the drive electrodes.

In one embodiment of the present invention, a method of forming a touch panel comprises forming a first conductor layer on a substrate; forming a semiconductor layer, corresponding to the first conductor layer, on the substrate, wherein the semiconductor layer comprises a channel; forming a first terminal and second terminal on the substrate, wherein the first terminal and second terminal connect to the channel; forming a piezoelectric material corresponding to the first conductor layer; forming a second conductor layer corresponding to the first conductor layer; and applying a voltage between the first conductor layer and the second conductor layer to generate a polarization of the piezoelectric material.

BRIEF DESCRIPTION OF THE DRAWINGS

The objectives and advantages of the present invention will become apparent upon reading the following description and upon referring to the accompanying drawings in which:

FIG. 1 schematically shows a touch panel according to one embodiment of the present invention;

FIG. 2 schematically shows a selection transistor and a pressure-sensing transistor, which are connected in series;

FIG. 3 is a cross-sectional view along line 3-3 of FIG. 2;

FIG. 4 schematically shows an amplifier circuit according to one embodiment of the present invention;

FIG. 5 schematically shows an amplifier circuit according to another embodiment of the present invention;

FIG. 6 is a cross-sectional view showing a pressure-sensing transistor according to another embodiment of the present invention;

FIG. 7 is a cross-sectional view showing a pressure-sensing transistor according to another embodiment of the present invention; and

FIG. 8 is a cross-sectional view showing a pressure-sensing transistor according to another embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 schematically shows a touch panel 1 according to one embodiment of the present invention. Referring to FIG. 1, the touch panel 1 comprises a plurality of basic sensing-units 11 arrayed in a matrix. The plurality of basic sensing-units 11 can be arranged, but is not limited to being, on a substrate 10. A plurality of drive electrodes 12 and a plurality of sensing electrodes 13 are formed on the substrate 10 and separate the sensing-units 11. Each sensing-unit 11 connects to an adjacent drive electrode 12 and an adjacent sensing electrode 13. The sensing unit 11 is configured to sense a touch position, or a single touch region or multi-touch positions (or regions). The drive electrode 12 and the sensing electrode 13 can be made of a transparent conductor,

such as indium tin oxide, so that the substrate **10** is transparent. A scanning voltage can be applied to the electrodes of each of two sets of drive electrodes **12** and sensing electrodes **13** one after another so as to retrieve a signal stored in each sensing unit **11**. Accordingly, a touch position, a single touch region, or multi-touch regions (or positions) can be determined.

In one embodiment, the substrate **10** is made of a non-semiconductor material.

Referring to FIG. 1, each sensing-unit **11** comprises a selection transistor **111** and a pressure-sensing transistor **112**. The selection transistor **111** and the pressure-sensing transistor **112** can be formed on the substrate **10** and can be connected in series.

Preferably, the selection transistor **111** comprises a first terminal (or a source) **1111**, a second terminal (or a drain) **1112**, and a third terminal (or a gate) **1113**. The pressure-sensing transistor **112** comprises a first terminal (a source) **1121**, a second terminal **1122** (or an end (P1, P2, or P3), as shown in FIG. 1; a drain), and a T end (FIG. 1), which is a terminal for polarizing a piezoelectric material. The first terminal **1111** of the selection transistor **111** connects to an adjacent sensing electrode **13**. The second terminal **1112** connects to the first terminal **1121** of the pressure-sensing transistor **112**. The third terminal **1113** can be a gate terminal and can connect to an adjacent drive electrode **12**. When a scanning voltage is applied to a drive electrode **12**, corresponding selection transistors **111** are activated, and each activated selection transistor **111** allows charges to flow into a corresponding pressure-sensing transistor **112** when a voltage is applied to a corresponding sensing electrode **13**. When pulse voltages are periodically applied to the drive electrodes **12** and the sensing electrodes **13**, the pressure-sensing transistors **112** can be scanned to detect if there is any current flowing through each pressure-sensing transistor **112**. Accordingly, a touch position, a single touch region, or multi-touch regions (or positions) can be detected.

In one embodiment, the selection transistor **111** comprises a p-type metal oxide semiconductor transistor. In one embodiment, the selection transistor **111** comprises an n-type metal oxide semiconductor transistor. In one embodiment, the pressure-sensing transistor **112** comprises a p-type metal oxide semiconductor transistor. In one embodiment, the pressure-sensing transistor **112** comprises an n-type metal oxide semiconductor transistor.

Referring to FIGS. 2 and 3, the pressure-sensing transistor **112** comprises a channel **1120**, which connects to the first terminal **1121** and the second terminal **1122**. The pressure-sensing transistor **112** can further comprise a piezoelectric material **1124** and an insulation layer **1125**. The insulation layer **1125** is formed on the channel **1120** and the piezoelectric material **1124** is formed on the insulation layer **1125**.

A plurality of black matrix materials **15** can be formed on the substrate **10**. The black matrix material **15** can be a conductive layer. The black matrix material **15** can be a light blocking metal layer. In one embodiment, each black matrix material **15** is disposed below a corresponding pressure-sensing transistor **112**. In one embodiment, each black matrix material **15** is disposed under a corresponding pressure-sensing transistor **112** and a corresponding selection transistor **111** so as to prevent light interference on the transistors. In one embodiment, the black matrix material **15** comprises chrome or nickel-chrome alloy. In one embodiment, the black matrix material **15** can shield electromagnetic waves. In one embodiment, the black matrix material **15** can be grounded and used with the T ends to polarize the piezoelectric materials.

In one embodiment, the pressure-sensing transistor **112** comprises an n-type metal oxide semiconductor transistor. The method of polarizing the piezoelectric material **1124** is described as follows: a suitable negative voltage is applied between the gate (i.e., T end) **1127** of the pressure-sensing transistor **112** and the corresponding black matrix material **15** so as to pole the piezoelectric material **1124** in an upward direction. In other words, positive charges are collected above the insulation layer **1125** and attract a small amount of negative charges to an upper surface of the channel **1120** of the pressure-sensing transistor **112**, which causes the pressure-sensing transistor **112** to be close to a threshold of current conduction and have a current of less than 1 micro-ampere (may not limited) flowing through. Consequently, when the pressure-sensing transistor **112** is touched, the strength of the upward polarization increases and more negative charges reside near the upper surface of the channel **1120**. As a result, the pressure-sensing transistor **112** is closed and allows larger currents of more than 10 micro-amperes (may not limited) to flow through the channel **1120**.

In another embodiment, the pressure-sensing transistor **112** comprises a p-type metal oxide semiconductor transistor. The method of polarizing the piezoelectric material **1124** is described as follows: a suitable positive voltage is applied between the gate **1127** of the pressure-sensing transistor **112** and the corresponding black matrix material **15** so as to pole the piezoelectric material **1124** in a downward direction. In other words, negative charges are collected above the insulation layer **1125** and attract a small amount of positive charges to an upper surface of the channel **1120** of the pressure-sensing transistor **112**, which causes the pressure-sensing transistor **112** to be close to a threshold of current conduction and have a current of less than 1 microampere (may not limited to) flowing through. Consequently, when the pressure-sensing transistor **112** is touched, the strength of the polarization increases and more positive charges reside near the upper surface of the channel **1120**. As a result, the pressure-sensing transistor **112** is closed and allows larger currents of more than 10 microamperes (may not limited to) to flow through the channel **1120**.

In one embodiment, the piezoelectric material **1124** comprises a polymer piezoelectric material. In one embodiment, the piezoelectric material **1124** comprises polyvinylidene fluoride or polyvinylidene difluoride (PVDF). In one embodiment, the piezoelectric material **1124** only has PVDF. In one embodiment, the piezoelectric material **1124** comprises a mixture which comprises PVDF and any one of the following materials: lead zirconate titanate (PZT), zinc oxide (ZnO), barium titanate (BaTiO₃), lithium niobate (LiNbO₃), and lead titanate (PbTiO₃).

Referring back to FIG. 1, the second terminal **1122** of the pressure-sensing transistor **112** of each sensing unit **11** may connect to an amplifier circuit **14**, which is configured to amplify a current signal read out from the corresponding pressure-sensing transistor **112**.

In one embodiment, referring to FIG. 4, the amplifier circuit **14** may comprise an inverting amplifier connected with resistors Rf and R1, wherein the ratio Rf/R1 is adjustable so as to amplify the output voltage of the pressure-sensing transistor **112**. In another embodiment, as shown in FIG. 5, the amplifier circuit **14** comprises a charge amplifier. The amplifier circuit **14** comprises an operation amplifier **141**, a first switch S1, a second switch S2, and a capacitor **142**. The capacitor **142** connects to an input terminal **1411** and an output terminal **1412** of the operation amplifier **141**. The first switch S1 connects to the input terminal **1411** of the operation amplifier **141** and the second terminal **1122** (or an

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output terminal) of the corresponding pressure-sensing transistor **112**. The second switch **S2** and the capacitor **142** are connected in parallel. In one embodiment, during open and closed operations, the first switch **S1** is out of phase with the second switch **S2**. In other words, when the second switch **S2** is closed, the first switch **S1** is open, and at the moment, the corresponding capacitor **142** discharges; alternatively, when the first switch **S1** is closed and the second switch **S2** is open, charges in the pressure-sensing transistor **112** will flow to the capacitor **142**; thus, the charge output of the pressure-sensing transistor **112** can be converted into a voltage, and a touch position, a single touch region, or multi-touch regions (or positions) can be detected on the panel.

In particular, as shown in FIG. 3, when the panel is touched, the piezoelectric material **1124** of the pressure-sensing transistor **112** is pressed, electricity can flow through the channel **1120** of the pressure-sensing transistor **112**, and at that moment, if the corresponding selection transistor **111** is activated, a current can flow from the corresponding sensing electrode **13**, through the corresponding pressure-sensing transistor **112**, and to the amplifier circuit **14**. Alternatively, if the piezoelectric material **1124** of the pressure-sensing transistor **112** is untouched, a current cannot flow through the corresponding pressure-sensing transistor **112**. By examining current from a pressure-sensing transistor **112**, it can be determined whether the pressure-sensing transistor is touched or not, and a touch position, a single touch region, or multi-touch regions (or positions) can be determined accordingly.

Referring to FIG. 3, the channel **1120** is a semiconductor layer. In one embodiment, the first terminal **1121** partially contacts an upper surface of the semiconductor layer **1120**. The second terminal **1122** partially contacts the upper surface of the semiconductor layer **1120**. In one embodiment, the first terminal **1121** and the second terminal **1122** of the pressure-sensing transistor **112**, the piezoelectric material **1124**, and the channel **1120** are partially overlapped in a vertical direction, and such design can significantly lower the resistance of the depletion layer adjacent to the second terminal, decrease power consumption, and increase response speed when the pressure-sensing transistor **112** is activated.

In one embodiment, the semiconductor layer **1120** comprises amorphous silicon, polysilicon, or monocrystalline silicon. The semiconductor layer **1120** may be doped with p-type impurities or trivalent elements to form a p-type semiconductor layer. Alternatively, the semiconductor layer **1120** may be doped with n-type impurities or pentavalent elements to form an n-type semiconductor layer.

The piezoelectric material **1124** is separated from the first and second terminals **1121** and **1122** of the pressure-sensing transistor **112** and the semiconductor layer **1120** by an insulation layer **1125**. The insulation layer **1125** can be made of an insulation layer having a high dielectric constant so that the sensitivity of the panel can be improved. In one embodiment, the insulation layer **1125** may comprise aluminum oxide. In one embodiment, the insulation layer **1125** comprises titanium dioxide. In one embodiment, the insulation layer **1125** comprises zirconium dioxide.

Referring to FIG. 3, the piezoelectric material **1124** may be covered by another insulation layer **1126**. The insulation layer **1126** can be made of an insulation layer having a high dielectric constant so that the sensitivity of the panel can be improved. In one embodiment, the insulation layer **1126** comprises titanium dioxide. In one embodiment, the insulation layer **1126** comprises zirconium dioxide.

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Referring to FIG. 3, the touch panel **1** comprises a circuit **23**, which includes a portion connecting with electronic components of the touch panel **1**. The circuit **23** may comprise a conductor layer **1127**, which may be formed on the insulation layer **1126**.

In one embodiment, when the pressure-sensing transistor **112** comprises a n-type metal oxide semiconductor transistor, the first terminal **1121** and the second terminal **1122** of the pressure-sensing transistor **112** may comprise a semiconductor material, such as silicon, and an n-type pentavalent material, such as phosphorous. In one embodiment, when the pressure-sensing transistor **112** comprises an n-type metal oxide semiconductor transistor, the first terminal **1121** and the second terminal **1122** of the pressure-sensing transistor **112** may comprise an n-type semiconductor, such as n-type amorphous silicon, n-type polysilicon, or n-type single crystalline silicon. In particular, when the pressure-sensing transistor **112** comprises an n-type metal oxide semiconductor transistor, the first terminal **1121** and the second terminal **1122** of the pressure-sensing transistor **112** are formed by using an electron beam (gun) to vapor-deposit powder formed from a mixture of silicon and pentavalent material such as phosphorous.

In one embodiment, when the pressure-sensing transistor **112** comprises a p-type metal oxide semiconductor transistor, the first terminal **1121** and the second terminal **1122** of the pressure-sensing transistor **112** comprises a semiconductor, such as silicon, and a trivalent material, such as boron. When the pressure-sensing transistor **112** comprises a p-type metal oxide semiconductor transistor, the first terminal **1121** and the second terminal **1122** of the pressure-sensing transistor **112** comprise p-type semiconductors, such as p-type amorphous silicon, p-type polysilicon, or p-type single crystalline silicon. In particular, when the pressure-sensing transistor **112** comprises a p-type metal oxide semiconductor transistor, the first terminal **1121** and the second terminal **1122** of the pressure-sensing transistor **112** are formed by using an electron beam (gun) to vapor-deposit powder formed from a mixture of silicon and trivalent material, such as boron.

Referring again to FIG. 3, the selection transistor **111** may comprise a semiconductor layer **1114**, which may comprise a channel. In one embodiment, the semiconductor layer **1114** comprises amorphous silicon, polysilicon, or single crystalline silicon. The semiconductor layer **1114** may be doped with p-type impurities to form a p-type semiconductor layer; or may be doped with n-type impurities to form an n-type semiconductor layer.

Referring to FIG. 3, the substrate **10** may comprise a glass substrate or a flexible substrate. The substrate **10** has two major surfaces, which may be covered by silicon dioxide layers **16** and/or positive photoresist layers **17** for insulating heat and blocking moisture penetration. In one embodiment, the sensing units **11** are directly formed on the silicon dioxide layer. In one embodiment, the sensing units **11** are directly formed on the photoresist layer **17**.

FIG. 6 is a cross-sectional view showing a pressure-sensing transistor **112a** according to another embodiment of the present invention. Referring to FIG. 6, for each pressure-sensing transistor **112a**, a black matrix material **15** is formed on the substrate **10**. A positive photoresist layer **17** covers the black matrix material **15**. A conductor layer **1127a**, for example aluminum or indium tin oxide, is formed on the positive photoresist layer **17** and corresponds to the black matrix material **15**. An insulation layer **18** covers the conductor layer **1127a**. A piezoelectric material **1124a** is formed correspondingly to the conductor layer **1127a** and on the

insulation layer 18. An insulation layer 1125a covers the piezoelectric material 1124a. A semiconductor layer 1120a is formed correspondingly to the piezoelectric material 1124a and on the insulation layer 1125a. Portions of the first terminal 1121a and the second terminal 1122a are formed underneath the semiconductor layer 1120a and directly connect to the semiconductor layer 1120a. An insulation material 1126a is formed on the semiconductor layer 1120a to block moisture penetration. A conductor layer 1128a, which is used together with another conductor layer 1127a and functions as a terminal for performing a poling process to the piezoelectric material 1124a, is formed on the insulation material 1126a. The conductor layer 1128a can be made of aluminum or indium tin oxide.

In one embodiment, the insulation layers 18, 1125a, and 1126a can be made of aluminum oxide. Aluminum oxide can lower the polarized voltage required for poling the piezoelectric material 1124a. Similarly, in one embodiment, the insulation layers 18, 1125a, and 1126a may be made of titanium dioxide. Similarly, in one embodiment, the insulation layers 18, 1125a, and 1126a may be made of zirconium dioxide.

FIG. 7 is a cross-sectional view showing a pressure-sensing transistor 112b according to another embodiment of the present invention. Referring to FIG. 7, for each pressure-sensing transistor 112b, a black matrix material 15 is formed on the substrate 10. A positive photoresist layer 17 covers the black matrix material 15. The first terminal 1121b and the second terminal 1122b are formed on the photoresist layer 17. An insulation layer 20 is formed between the first terminal 1121b and the second terminal 1122b. A semiconductor layer 1120b is formed on the insulation layer 20 and portions of the first terminal 1121b and the second terminal 1122b, wherein the semiconductor layer 1120b directly contacts the portions of the first terminal 1121b and the second terminal 1122b. An insulation layer 21 covers the insulation layer 20 and portions of the first terminal 1121b and the second terminal 1122b. An insulation layer 1125b covers the semiconductor layer 1120b. A piezoelectric material 1124b is formed correspondingly to the semiconductor layer 1120b and on the insulation layer 1125b. An insulation layer 1126b covers the piezoelectric material 1124b. A conductor layer 1127b made of, for example aluminum or indium tin oxide, covers the insulation layer 1126b and portions of the first terminal 1121b and the second terminal 1122b. The conductor layer 1127b can be used together with the black matrix material 15 for performing a poling process to the piezoelectric material 1124b.

In one embodiment, the insulation layers 20, 1125b, and 1126b may be made of aluminum oxide to lower the voltage required for poling the piezoelectric material 1124b. Similarly, in one embodiment, the insulation layers 20, 1125b, and 1126b may be made of titanium dioxide. Similarly, in one embodiment, the insulation layers 20, 1125b, and 1126b may be made of zirconium dioxide.

FIG. 8 is a cross-sectional view showing a pressure-sensing transistor 112c according to another embodiment of the present invention. Referring to FIG. 8, the pressure-sensing transistor 112c is similar to the pressure-sensing transistor 112a of FIG. 6, one major difference is that the first terminal 1121a and the second terminal 1122c of the pressure-sensing transistor 112c extend from an insulation layer 18 to an upper surface of the semiconductor layer 1120c and directly contact the upper surface. Above the semiconductor layer 1120c is an insulation material 1126c, and below the semiconductor layer 1120c is an insulation

material 1125c. The insulation materials 1125c and 1126c can block moisture penetration.

Moreover, a conductor layer 1128c made of, for example aluminum or indium tin oxide, is formed on the insulation material 1126c. The conductor layer 1128c can be used together with another conductor layer 1127c for performing a poling process to the piezoelectric material 1124c.

In addition, one embodiment of the present disclosure provides a method of forming a touch panel. The steps of the method are explained by using the embodiment of FIG. 3; however, the method is not limited to the embodiment of FIG. 3. The method can be applied on the embodiments of FIGS. 6 to 8 and alternative embodiments without departing from the scope of the following claims. Referring to FIG. 3, the method forms a black matrix material 15 on a substrate 10. Next, semiconductor layers 1114 and 1120 are formed on the substrate 10, wherein the semiconductor layers 1114 and 1120 are on the black matrix material 15. Thereafter, a first terminal 1111, a second terminal 1112, a first terminal 1121 and a second terminal 1122 are formed on the substrate 10, wherein the first terminal 1111 and the second terminal 1112 have portions contacting the semiconductor layer 1114; and the first terminal 1121 and the second terminal 1122 contact the semiconductor layer 1120. Subsequently, insulation layers 1115 and 1125 are formed on the substrate 10, wherein the insulation layers 1115 and 1125 respectively cover the semiconductor layers 1114 and 1120. Further, a piezoelectric material 1124 is formed on the substrate 100, wherein the piezoelectric material 1124 is formed on the insulation layer 1125 and corresponds to the black matrix material 15. Moreover, a circuit 23 including a conductor layer 1127 is formed on the substrate 10. In addition, a voltage is applied between the conductor layer 1127 and the black matrix material 15 (or the conductor layer 1128a of FIG. 6 or the conductor layer 1128c of FIG. 8) so as to perform a poling process to the piezoelectric material 1124.

In some embodiments, a touch panel comprises a pressure-sensing transistor having a piezoelectric material which has a property of piezoelectricity and exhibits electrical potential when it is pressed, and the electrical potential can activate the pressure-sensing transistor to allow a current to flow through the pressure-sensing transistor. The location of a touch can be determined by examining which pressure-sensing transistor allows a current to flow. In some embodiments, a touch panel comprises a plurality of sensing-units, and each sensing unit comprises a selection transistor and a pressure-sensing transistor. The sensing-units can be used to determine a touch position, a single touch region, or multi-touch regions (or positions).

The above-described embodiments of the present invention are intended to be illustrative only. Those skilled in the art may devise numerous alternative embodiments without departing from the scope of the following claims.

What is claimed is:

1. A touch panel comprising:

- a substrate;
- a plurality of transparent drive electrodes arranged in a matrix and formed on the substrate;
- a plurality of transparent sensing electrodes arranged in a matrix and formed on the substrate; and
- a plurality of basic sensing-units arranged in a matrix and formed on the substrate, each basic sensing-unit comprising:
 - a pressure-sensing transistor comprising a first terminal, a second terminal, a channel connecting the first and second terminals, a dielectric layer formed on the channel, a piezoelectric material formed on the dielec-

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tric layer, wherein the piezoelectric material comprises PVDF (polyvinylidene fluoride or polyvinylidene difluoride), or a mixture of PVDF and any one of lead zirconate titanate, zinc oxide, barium titanate, lithium niobate, or lead titanate; and

a selection transistor formed on the substrate, the selection transistor comprising a first terminal, a second terminal, and a third terminal, wherein the first terminal of the selection transistor connects to a corresponding one of the sensing electrodes, the second terminal of the selection transistor connects to the first terminal of the pressure-sensing transistor, and the third terminal of the selection transistor is a transistor gate and connects to a corresponding one of the drive electrodes.

2. The touch panel of claim 1, wherein each pressure-sensing transistor comprises a semiconductor layer including the channel, wherein each of the first and second terminals of each pressure-sensing transistor partially contacts an upper or lower surface of the corresponding semiconductor layer.

3. The touch panel method of claim 2, wherein the piezoelectric material is on the semiconductor layer.

4. The touch panel of claim 2, wherein the piezoelectric material is below the semiconductor layer.

5. The touch panel of claim 2, wherein a portion of the first terminal and a portion of the second terminal of each pressure-sensing transistor overlap the piezoelectric material and the channel of the pressure-sensing transistor.

6. The touch panel of claim 1, further comprising a plurality of amplifier circuits, wherein each amplifier circuit connects to the second terminal of a corresponding one of the pressure-sensing transistors.

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7. The touch panel of claim 6, wherein the amplifier circuit is a charge amplifier.

8. The touch panel of claim 6, wherein each amplifier circuit comprises an operational amplifier, a first switch, a second switch, and a capacitor, wherein the capacitor connects to an input and an output of the operation amplifier; the first switch connects to the input terminal of the operational amplifier and the second terminal of the corresponding pressure-sensing transistor; and the second switch and the capacitor are connected in parallel; wherein the first switch is out of phase with the second switch.

9. The touch panel of claim 1, further comprising a plurality of black matrix materials, wherein each black matrix material is disposed below the corresponding pressure-sensing transistor and the corresponding selection transistor, wherein each black matrix material comprises chrome and is grounded.

10. The touch panel of claim 1, wherein when each pressure-sensing transistor comprises an NMOS transistor, the first and second terminals of each pressure-sensing transistor comprise n-type amorphous silicon, polysilicon, or single crystalline silicon; or, when each pressure-sensing transistor comprises a PMOS transistor, the first and second terminals of each pressure-sensing transistor comprise p-type amorphous silicon, polysilicon, or single crystalline silicon.

11. The touch panel of claim 1, configured to detect a touch position or a single touch region, or multi-touch positions or regions.

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